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# DIFFICULTIES ENCOUNTERED IN THE USE OF AN APHID-INJECTION METHOD FOR THE TRANSMISSION OF POTATO LEAFROLL VIRUS[1]

WALTER C. MUELLER[2] AND A. FRANK ROSS[3]

## INTRODUCTION

Research on purification and properties of potato leafroll virus is hampered by the lack of a method for routine detection of the virus in liquid extracts. A technique that shows promise as a solution to this problem is that involving injection of virus preparations into green peach aphids, *Myzus persicae* Sulz., which then transmit the virus to appropriate test plants. This procedure has recently been used successfully in other kinds of studies with potato leafroll virus in several laboratories (1, 2, 3, 9).

An injection apparatus that is simple in design and convenient to use was developed. It proved highly successful in concurrent work with another aphid-borne persistent virus, barley yellow dwarf virus, with which it gave consistent and reproducible results (6). Some difficulites were encountered in the use of this microinjection method for the transmission of potato leafroll virus.

## MATERIALS AND METHODS

All test plants were grown from seed germinated in vermiculite; seedlings in the cotyledon stage were transplanted to 3- or 4-in. pots. Supplementary light was given all plants during the winter.

The strain of potato leafroll virus used induced pronounced symptoms in *Physalis floridana* Rydb.; it was isolated in 1956 from an unnamed potato selection and maintained by regular transfers in *Datura stramonium* L. Aphids to be used as sources of the virus were fed for at least a week on infected plants of *D. stramonium* in a building separate from that used for nonviruliferous colonies.

Only the adult wingless form of the green peach aphid was used for injection. A few tests involved the aphid strain commonly found on potatoes in this area; these were maintained on radish (*Raphanus sativus* L.), which is immune from leafroll virus. This strain will be referred to subsequently as the radish strain. A strain capable of surviving on tobacco (*Nicotiana tabacum* L.), obtained from Dr. K. Maramorosch and maintained on tobacco, was used unless otherwise stated. In comparative tests, the 2 strains transmitted equally well after acquiring virus by feeding on infected *D. stramonium*; both transmitted to 100% of the test plants (*P. floridana*) when 2 aphids were tested on each plant. The original colony of each was started from nymphs obtained from a single mature female. The colonies were maintained by weekly transfer of infested leaves to fresh plants. All nonviruliferous aphids were maintained in the greenhouse in insectary chambers, which were provided with supplementary light during winter months. The temperature in the

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chambers was held at 72 F during the winter; it fluctuated considerably during the spring and fall and frequently exceeded 100 F in the summer.

The microinjection device, consisting of a glass needle attached to a rubber syringe bulb, and the method used for injection are described elsewhere (6). Unless otherwise stated, test feedings were made on seedlings of *P. floridana*, 2 injected aphids on each; seedlings were used when the first true leaf was ¼ in. long. The infested seedlings were then covered with clean cylindrical cages made from Pyralin and fine-mesh cheesecloth. Observations of the mortality of the aphids were made daily. All living aphids that had left the seedlings since the previous observation were returned to the seedlings. After 5 days, the cages were removed and the plants exposed for 10 minutes to nicotine sulphate vapor in a closed chamber; afterwards, the plants were placed in the greenhouse, which was fumigated regularly.

Controls, consisting of nonviruliferous aphids from the same colony as the aphids injected, were tested in every experiment. Because of space and plant limitations, these aphids were confined on fewer plants than were those used in an experiment, but the number of control insects was always equal to or greater than the number injected.

## Results

### *Transmission of Virus by Aphids Injected with Haemolymph Extracts*

Since injected extracts of solanaceous plants were found to be highly toxic to aphids, the material for injection was prepared from haemolymph of viruliferous aphids. After removal from the source plants, aphids were placed in a 4-mm glass tube and weighed; saline (0.85% NaCl) was added and the aphids then ground with a glass rod shaped to fit the contours of the tube. The resulting material was centrifuged for 10 minutes at 3550 G in an angle centrifuge; this resulted in a packed layer of aphid remains, a cloudy greenish-colored aqueous phase, and a top layer of fatty material. The aqueous phase was removed with a hypodermic syringe and injected either directly or after filtration through a Swinny B-D Filter Adapter attached to a hypodermic syringe. Streptomycin sulfate was added to some preparations.

The amount of transmission was low in all experiments (Table 1). Aphid mortality, which varied greatly, appeared to be associated with feeding behavior. The aphid counts represent the total number of aphids living, not just those feeding. Usually the aphids fed well for 24-48 hours after injection; therefore, aphids dying within this time are presumed to have died as a result of injection. Later, most aphids ceased feeding and wandered from the seedlings. These aphids, when replaced, usually fed for various periods and then wandered again; such aphids were kept alive only by being placed back on the seedlings daily. An occasional aphid fed on the seedlings for the whole 5-day test-feeding time, but survival for 5 days did not assure transmission; the majority of these aphids did not transmit. Transmission never occurred however, if both aphids died during the first 3 days after injection. This is not necessarily evidence that a latent period of 2 to 3 days is necessary for transmission, but it does represent the only consistent pattern observed in all these experiments.

TABLE 1.—*Transmission of Myzus persicae to Physalis floridana of potato leafroll virus acquired by injection of haemolymph extracts diluted with saline (0.85% NaCl).*

| Treatment of extracts | | No. aphids injected | No. aphids alive after indicated no. of days | | | Transmission[1] |
|---|---|---|---|---|---|---|
| Treatment | Dilution | | 1 | 3 | 5 | |
| Unfiltered | 1-5 | 320 | 310 | 219 | 102 | 18/160 |
| Unfiltered | 1-5 | 440 | 431 | 248 | 137 | 8/200 |
| Filtered | 1-5 | 440 | 418 | 238 | 151 | 7/200 |
| Filtered | 1-5 | 80 | 80 | 49 | 29 | 2/40 |
| | 1-10 | 64 | 64 | 24 | 7 | 2/32 |
| | 1-20 | 64 | 64 | 53 | 41 | 0/32 |
| Filtered + streptomycin[2] | 1-5 | 96 | 95 | 46 | 40 | 4/48 |
| | 1-10 | 96 | 90 | 52 | 33 | 1/48 |
| Controls (>936 noninjected aphids) | | | | | | 0/195 |

[1]Number of test plants infected/number infested (2 injected aphids per plant).
[2]Extracts treated with 5 ppm streptomycin sulfate.

In 4 experiments with filtered extracts, the preparations were stored at 2 C after the first injection and used for injection 1, 2, and 3 days later. Infectivity persisted for at least 3 days after preparation of the extracts (Table 2). This finding may be very important for future work on purification of the virus. The failure to detect any decrease in infectivity is of little significance, for the procedure used was not quantitative.

TABLE 2.—*Transmission by Myzus persicae to Physalis floridana of potato leafroll virus acquired by injection of filtered haemolymph extracts diluted 1-5 with saline and stored at 2 C for 1, 2, or 3 days.*

| Length of storage (days) | No. aphids injected | No. aphids alive after indicated no. of days | | | Transmission[1] |
|---|---|---|---|---|---|
| | | 1 | 3 | 5 | |
| 0 | 160 | 160 | 112 | 73 | 5/80 |
| 1 | 120 | 120 | 89 | 38 | 3/80 |
| 2 | 120 | 118 | 96 | 48 | 6/60 |
| 0 | 40 | 40 | 23 | 15 | 1/20 |
| 1 | 40 | 39 | 22 | 17 | 0/20 |
| 3 | 40 | 40 | 24 | 24 | 1/20 |
| Controls (>200 noninjected aphids) | | | | | 0/60 |

[1]Number of test plants infected/number infested (2 injected aphids per plant).

In 3 of the 4 experiments, transmission was not obtained after injection of extracts later found to contain active virus; this demonstrates that lack of transmission in any one experiment does not necessarily indicate absence of the virus in the extract. The method, therefore, cannot be used with certainty until a much higher level of efficiency is reached routinely.

*Comparison of Two Strains of Myzus Persicae as Transmitters of Virus Acquired by Injection*

Since variation in the ability of various clones of aphids to transmit viruses has been noted (7, 8, 10), the tobacco and radish strains were compared as transmitters of virus acquired by injection of haemolymph from viruliferous aphids. The haemolymph was transferred directly from aphid to aphid, with that from a single source aphid being transferred to only one aphid; each of the injected aphids thus received a fresh source of the virus.

The two strains did not differ in ability to survive injection or to transmit leafroll virus after injection. Injected aphids of the tobacco strain transmitted to 5 of 75 test plants; those of the radish strain transmitted to 6 of 75. Of the 150 aphids of each strain injected, the numbers surviving, of the tobacco and radish strain, respectively, were 144 and 145 after 1 day, 105 and 90 after 3 days, and 38 and 24 after 5 days.

*Comparative Transmission, after Injection, by Progenies of Aphids Recorded as Transmitters and Nontransmitters of Injected Virus.*

Williams (11) found that individual green peach aphids from the same population differed greatly in ability to transmit leafroll virus after a 72-hour acquisition feeding. Moreover, this ability to transmit was heritable. Since it is possible that a parallel situation may exist with respect to ability to transmit after injection, an attempt was made to compare the transmission by progenies of individuals that had transmitted after injection with that by progenies of individuals that had not transmitted.

Fifty aphids injected directly with haemolymph from viruliferous aphids were placed individually on seedlings of *P. floridana*. After a 5-day test feeding, surviving aphids and all newly emerged nymphs were placed on individual tobacco seedlings and allowed to form colonies. When the transmission results were known, the individual colonies were combined to form 2 colonies: [i] progency of all aphids that had transmitted and [ii] progeny of all aphids that had not transmitted. Aphids in these 2 colonies were then compared for their ability to transmit the virus after injection.

Eighty aphids from each colony were injected directly with haemolymph from viruliferous insects. Survival for 3 and 5 days, respectively, was 47 and 21 for progeny of nontransmitters and 40 and 17 for that of transmitters. Aphids derived from the nontransmitters transmitted to 8 of 40 test plants, whereas those derived from transmitters effected transmission to 5 of 40 plants. Apparently, the variability in ability to transmit noted in the present work was due to a heritable trait of some aphids only.

*Unsuitability of Physalis Floridana as Host Plant for Myzus Persicae*

It became evident that the high mortality of the injected aphids 2-5 days after injection was caused by factors other than injection injury. The behavior of aphids on *P. floridana* was in marked contrast to behavior of aphids injected with water and placed on tobacco or radish. Such aphids rarely wandered off tobacco or radish plants; instead they fed well, continued to grow, and formed large colonies. It appeared that either the injected material caused a delayed toxic reaction or that *P. floridana* is not a suitable host plant for the injected aphids. A comparison was made, therefore, of the survival of the radish strain of *M. persicae* on radish, *P. floridana*, and *D. stamonium* after injection with haemolymph from viruliferous aphids.

*P. floridana* proved inferior to radish as host for injected *M. persicae* (Table 3). Aphids surviving on *P. floridana* ceased growing and produced very few young. In marked contast, comparable injected aphids placed on radish continued to grow and to produce large colonies. No indication was noted of a delayed toxic reaction in these aphids.

TABLE 3.—*Survival of, and transmission of leafroll virus by, Myzus persicae injected with haemolymph from viruliferous aphids and then placed on different host plants.*

| Host plant | No. aphids injected | No. of aphids alive after indicated no. of days | | | Transmission[1] |
|---|---|---|---|---|---|
| | | 1 | 3 | 5 | |
| Radish | 80 | 78 | 78 | 71 | |
| *Physalis floridana* | 80 | 79 | 51 | 29 | 2/40 |
| *Datura stramonium* | 55 | 55 | 49 | 43 | 0/15[2] |
| Radish | 256 | 249 | 242 | 232 | |
| *P. floridana* | 256 | 248 | 152 | 45 | 0/128 |
| Controls (> 336 noninjected aphids on *P. floridana*) | | | | | 0/52 |

[1]Number of test plants infected/number infested (2 injected aphids per plant).
[2]Five injected aphids per plant.

*D. stramonium* was intermediate as a host for the aphids; survival was much better than on *P. floridana*, but aphids on *D. stramonium* neither grew as large nor produced as large colonies as did those on radish. Unfortunately, *D. stramonium* appears to be unsatisfactory for testing the transmitting ability of injected aphids. It is less susceptible to leafroll virus than is *P. floridana* (4), and no transmission was obtained in these tests nor in 4 further attempts to use it as a test plant for aphids injected directly with haemolymph.

Although Kirkpatrick and Ross (5) state that *P. floridana* is unsuitable as a rearing host for *M. persicae*, no other mention of the erratic behavior of *M. persicae* on *P. floridana* was found in the literature, presumably because it may not be a factor in the ordinary transmission of leafroll virus. Aphids that acquire virus by feeding are able to transmit the virus to *P. floridana* in less than 1 day (5), hence longer survival is not essential.

Presumably, successful transmission after injection depends upon the ability of aphids to remain alive and in good condition until the injected virus passes into the salivary glands and is injected into the test plants. The time needed for this appears to vary with the conditions of injection; it may be as short as 20 hours (2) or as long as 10 days (9). Observations indicate that it occurred in about 2 days under the conditions used here.

*Use of Radish as Intermediate Host for Myzus Persicae after Injection*

Several attempts were made to obtain a variant strain of *M. persicae* that would survive on *P. floridana*. Attempts were made to maintain aphids on large plants of *P. floridana;* in all cases, however, the colonies were lost in 7-10 days. Also, tests were made with the progeny of aphids that did survive for 5 days after injection and appeared to be feeding well. None of these aphids, however, showed their parents' ability to survive on *P. floridana*. In view of these difficulties, an attempt was made to prolong the life of injected aphids by confining them on radish seedlings immediately after injection, i.e. during the supposed latent period when they are unable to transmit the virus.

Aphids of the radish strain were injected with haemolymph from viruliferous aphids and placed immediately on radish. After 1-7 days, survivors were transferred to *P. floridana* (3-leaf stage) for a 3-day test feeding. Five aphids were tested on each seedling except that the last seedling infested usually received fewer than 5. The period of confinement on radish had no effect on transmission nor on survival or behavior of the aphids after their transfer to *P. floridana* (Table 4). Many aphids refused to feed after transfer to *P. floridana;* in some tests, over 50% of the surviving aphids died within the first day. As a result, the number of aphids surviving this 3-day test feeding was not greater than the number surviving the 5-day test feeding used in the previous experiments.

TABLE 4.—*Transmission of potato leafroll virus to Physalis floridana by Myzus persicae fed on radish for different lengths of time after being injected with haemolymph from viruliferous aphids.*

| Days on radish | No. aphids injected | No. aphids surviving | | Transmission[1] |
|---|---|---|---|---|
| | | Radish | *P. floridana* (3 days) | |
| 1 | 300 | 289 | 125 | 2/59 |
| 2 | 190 | 184 | 96 | 3/48 |
| 3 | 160 | 149 | 40 | 5/31 |
| 4 | 60 | 52 | 11 | 0/11 |
| 5 | 375 | 359 | 81 | 7/72 |
| 7 | 25 | 21 | 11 | 1/5 |
| Controls (> 375 noninjected aphids) | | | | 0/72 |

[1]Number of test plants infected/number infested. Aphids surviving on radish were divided 5 to each test plant, except that the last plant infested usually received fewer than 5.

*Seasonal Variation in the Transmission by Aphids of Virus Acquired by Injection*

During the 18-month period of the previous experiments, a seasonal variation in the total transmission became evident. Transmission was best in spring and fall, nil in summer, and very low in mid-winter (Fig. 1).

The periods of best transmission in the spring and fall coincide with the periods when the aphids are easier to maintain in the greenhouse and when they reproduce the fastest. This suggests that transmission by injected aphids may be dependent upon their physiologic condition, which presumably can be affected directly by light and temperature or indirectly through effects on growth and physiology of the host plants.

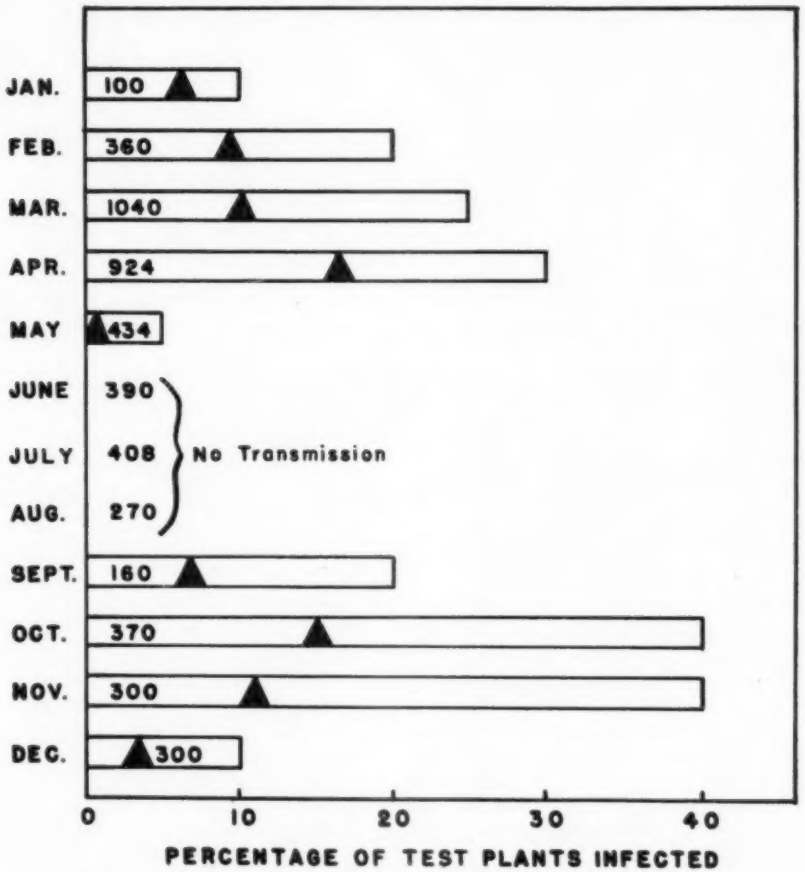


FIG. 1.—Seasonal variation in the transmission of injected potato leafroll virus by *Myzus persicae* in all experiments conducted. The ranges in percentage transmission are indicated by bars, the averages by triangles; the total numbers of aphids injected indicated by numerals.

Tests were made, therefore, with aphids reared under constant conditions. Nonviruliferous colonies were transferred to an air-conditioned room maintained at 72 F and provided with approximately 700 ft-c of light for 15 hours daily. These colonies were transferred weekly to young radish plants started in the greenhouse. In several experiments extending over several months, aphids were injected with virus-containing haemolymph and placed on radish seedlings for 3 days before being transferred to seedlings of *P. floridana* (3-leaf stage), 5 aphids per plant. All operations subsequent to injection were carried out in the greenhouse with greenhouse-grown plants. Neither transmission nor survival was better than in similar experiments with aphids reared in the greenhouse. Transmission was again best in those experiments in which the survival of the aphids was best. In tests involving 194 plants of *P. floridana* and 830 injected aphids, only 13 plants developed symptoms.

## Discussion

The difficulty encountered in the use of *P. floridana* as a host plant for *M. persicae* has greatly hindered the development of a microinjection method for the assay of potato leafroll virus. Because nearly 100% transmission of barley yellow dwarf virus was attained in concurrent tests with the injection method used here (6), and also because attempts to increase transmission by manipulation of the material injected were unsuccessful, it seems probable that the poor and inconsistent results with leafroll virus are related, at least in part, to the main constant feature in these experiments, the erratic behavior and high mortality of *M. persicae* on *P. floridana*.

The significance of this behavior of *M. persicae* on *P. floridana* as a factor in transmission is difficult to assess. Harrison (2) and Stegwee and Ponsen (9) reported 100% and 55% survival, respectively, 3 days after injection. Mortality was apparently the result of injection; if there was any erratic behavior of the aphids on *P. floridana*, it was not reported. Both Harrison (2) and Stegwee and Ponsen (9), however, reported the existence of a latent period after injection, of which indications were also found in the present work, i.e. transmission was attained only in those instances when the aphids had fed constantly for at least 3 days after injection. The ability to keep aphids alive and feeding, therefore, appears to be necessary to obtain consistent results. That this is not the only requirement is indicated by the fact that use of radish as an intermediate host resulted in neither an increase in transmission nor an improvement in the behavior of the aphids after their transfer to *P. floridana*. Indeed, the fact that injected aphids fed well and survived the test feeding period on *P. floridana* did not in itself guarantee that the aphids would transmit the virus; the majority of such aphids did not. Although our results in general suggest that only a small percentage of the aphids of the clones used were able to transmit after injection, the similarity of results with different aphid clones indicates that this was not due to a heritable character. Possibly many aphids surviving longer than the latent period failed to transmit because of erratic feeding on *P. floridana*, i.e. they did not probe deep enough or long enough to effect transmission. By chance, a few may have done so.

That environmental factors affect transmission of virus acquired by injection is strongly indicated by the seasonal fluctuation in transmission. The inconsistent transmission by aphids reared under constant conditions does not necessarily mean that the physiologic conditions of the aphids at time of injection is not important, for the conditions used may not have been optimum, but it does suggest that environmental conditions affect transmission in other ways. Conditions best for rearing aphids may not be best for transmission. Environmental conditions could affect the virus content of the haemolymph of the source aphids through effects on the virus content and/or accessibility in source plants, on the feeding behavior of aphids during acquisition, and on virus stability. Fluctuations in light and/or temperature may contribute to irregularities in the inoculation of test plants by altering the susceptibility of the test plants and by influencing the feeding behavior of aphids, either directly or through an effect on the attractiveness of *P. floridana* as a food plant.

In a few of the experiments, 40% of the test plants infested with injected aphids became infected. If such a percentage of transmission were obtained consistently, the method would be usable for the routine assay of leafroll virus; however, results were extremely variable even during the months seemingly most favorable for transmission. Until the factors affecting transmission are identified and controlled, the lack of transmission in any one experiment will not necessarily indicate the absence of virus in the preparations used for injection.

The discrepancy between the transmission obtained here and that obtained by Harrison (2) and Stegwee and Ponsen (9) may be due to differences in the virus strains, in aphid clones, in environmental conditions, or in injection techniques. The excellent transmission of barley yellow dwarf virus obtained with the injection technique used here (6) does not support the last possibility; the first two could be tested by an exchange of virus and aphids. Since the seasonal variation in transmission observed here was not reported by these workers, it appears that the environmental conditions under which they worked may be more conducive for these studies than those in Ithaca.

It is obvious that one primary consideration in finding the factors affecting transmission is the removal of the uncertainty of the effect of the unsuitability of *P. floridana* as a host plant for *M. persicae*. The attempt to find a variant clone of *M. persicae* that can survive on *P. floridana* may have failed because all aphids of each strain used descended from one stem mother; the existence of such strains capable of surviving on *P. floridana* is implied in the excellent survival obtained by Harrison (2). Routine use of the injection method with leafroll virus may be delayed until better test plants are discovered. *D. stramonium* and *P. angulata* L., species frequently used as test plants for this virus, perhaps should be thoroughly tested for use in the aphid-injection procedure, but neither is as good a host for *M. persicae* as is radish nor as susceptible to the virus as is *P. floridana*. A test plant worthy of a trial is *Nicandra physaloides* Gaertn., which was described by Williams (11) as less susceptible than *P. floridana* but upon which aphids form large colonies.

## Summary

An aphid-injection method that gave excellent results with barley yellow dwarf virus failed to do so in concurrent tests with potato leafroll virus. Although potato leafroll virus was transmitted to plants by green peach aphids injected with haemolymph extracts from viruliferous aphids, the amount of transmission was low and inconsistent. The erratic feeding behavior of the injected aphids on the test plant, *Physalis floridana*, appeared to be a major factor contributing to poor transmission. Neither the transmission nor the survival of the aphids was improved by allowing the injected aphids to feed on radish before transfer to *P. floridana*. Progeny from aphids that transmitted following injection did not effect more transmission than progeny of nontransmitters. Transmission was best in spring and fall, low in mid-winter, and nil in summer. Ability to transmit after injection appeared to be associated with the physiologic condition of the aphids, but aphids reared under one set of constant conditions before injection did not effect more transmission than those reared under greenhouse conditions. Virus activity in haemolymph extracts was not destroyed by storage at 2 C for 3 days.

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# LABORATORY TESTING OF THE POTATO FOR PARTIAL RESISTANCE TO *PHYTOPHTHORA INFESTANS*[1]

W. A. HODGSON[2]

## INTRODUCTION

Resistance in the potato to the late blight pathogen *Phytophthora infestans* (Mont.) de Bary is generally considered to be of two types; one controlled by four or more dominant genes which are frequently referred to as major genes or R-genes, and the other governed by a polygenic system of what are sometimes called minor genes. Major gene resistance has been characterized as a hypersensitive reaction of the host to infection and plants can be classified as either resistant or susceptible according to whether or not they are "immune" to specific races of the fungus. Minor gene resistance on the other hand has been characterized as a partial or an intermediate type of resistance to all known races of the fungus. Plants with partial resistance are not immune to any race but for reasons not as yet clearly understood, the development of the fungus is not as rapid on them as it is on susceptible varieties.

The expression of partial resistance is greatly affected by differences in environmental conditions and consequently it is difficult to assess. The method of assessment generally employed at present is to expose plants to the disease in the field for a period of two or more years. This method is laborious and time consuming, and moreover, it frequently gives unsatisfactory results since its success is dependent upon the presence of a race of the fungus pathogenic to the plants under test and upon weather conditions favorable for late blight development. The apparent need for a better method of testing for partial resistance has led to a consideration of various factors which may affect the expression of resistance. Black and Gallegly (2) have suggested that "variations in such factors as virulence of the pathogen, concentration of inoculum, temperature, relative humidity, soil fertility and age of the plant, may have a significant effect upon the growth of the fungus and the reaction of the plant." More recently Lowings and Acha (7) have shown that nitrogen nutrition and plant senescence affect the susceptibility of the variety Majestic. This paper reports the results of observations on the effect of concentration of inoculum and age of the leaf on the expression of partial resistance and on its measurement under laboratory conditions.

## MATERIALS AND METHODS

The potato varieties used were grown in 7-inch pots in the greenhouse. Inoculum was a suspension of zoospores of what has been tentatively called race 1,2,3,4,6 of the fungus (4). Inoculum was obtained from 7-day old cultures grown on rye meal agar. Spore suspensions were prepared in glass-distilled water and spore counts were made using a Levy Counting Chamber. Inoculum was applied with a medicine dropper which delivered a drop having an average volume of approximately 0.045 ml. The plant

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material inoculated consisted of discs 15 mm in diameter cut from leaves with a cork-borer. Immediately after cutting, the discs were placed, upper surface uppermost, on moist blotting paper in enameled trays and covered with a glass lid. The inoculated discs were incubated in a moist chamber kept at approximately 60 F and examined after one week when they were scored according to the presence or absence of sporulation.

## Results

### *The effect of spore concentration*

In preliminary tests with varieties of known field resistance it was found that when discs were inoculated by spraying with a dilute zoospore suspension, as suggested by Muller (9), wide variations in disease readings were obtained between replications in any one test and between tests.

General observations suggested that variability was due to an unevenness in the amount of inoculum applied to the discs, and to differences in the concentration of inoculum used in the various tests. To investigate the effect of differences in the amount of inoculum, discs from leaves of the varieties Noordeling, Voran, Sebago and Cherokee were inoculated with one and two drops of a dilute zoospore suspension. The results of these tests, one of which is given in Table 1, showed that the application of two drops of inoculum resulted in a higher percentage of fructifying discs than did the application of one drop. The importance of applying the same amount of inoculum to discs of all varieties was demonstrated by the fact that the resistant varieties, Noordeling and Voran, when inoculated with two drops of inoculum had about the same percentage of sporulating discs as the moderately resistant Sebago and the susceptible Cherokee inoculated with one drop.

Table 1.—*Effect of amount of inoculum on sporulation of P. infestans on discs from four potato varieties.*

| Drops of inoculum | Percentage of discs showing sporulation | | | |
|---|---|---|---|---|
| | Noordeling | Voran | Sebago | Cherokee |
| 1 | 2[1] | 2 | 25 | 38 |
| 2 | 31 | 33 | 54 | 86 |

[1]Each figure based on the inoculation of 48 discs.

The effect of spore concentration on the percentage of sporulating discs was investigated in a second set of experiments in which leaf-discs were inoculated with drops of inoculum containing a known number of spores. These experiments showed that for all varieties tested the percentage of sporulating discs decreased as the concentration of inoculum was decreased below that required to cause 100% of the discs to show sporulation. In addition, varieties were found to differ in the concentration of inoculum required to cause any given percentage of sporulating

TABLE 2.—*Effect of concentration of inoculum on sporulation of P. infestans on discs from four potato varieties*

| Spores per drop | Percentage of discs showing sporulation | | | |
|---|---|---|---|---|
| | Noordeling | Voran | Sebago | Cherokee |
| 400 ..... | 43[1] | 36 | 53 | 75 |
| 200 ..... | 18 | 18 | 47 | 67 |
| 50 ..... | 10 | 6 | 28 | 40 |

[1]Each figure based on the inoculation of 36 discs.

discs. This is illustrated in Table 2 where it is shown that 40% of discs of Cherokee showed sporulation when inoculated with 50 spores per drop, whereas to obtain approximately the same percentage with Sebago and Noordeling 200 and 400 spores per drop respectively were required. These observations indicate that to estimate accurately the relative resistance of varieties, it is necessary to apply the same concentration of inoculum to the discs of each variety.

*The effect of leaf position*

Observations made during the course of the above work suggested that leaves from certain parts of the potato plant were more susceptible to blight than were leaves from other parts. Tests were therefore made in which discs cut from leaves taken from the top, middle and bottom of the plant were inoculated with a drop of inoculum containing a known number of zoospores. In all varieties tested the results were similar to those obtained in three tests with the variety Noordeling shown in Table 3. The top leaves were the most resistant, the bottom the most susceptible and the middle intermediate. In other tests in which discs from the three

TABLE 3.—*Effect of leaf position on the percentage of discs showing sporulation.*

| Leaf position | Percentage of discs showing sporulation | | |
|---|---|---|---|
| | Test I | Test II | Test III |
| Top ..... | 1[1] | 9 | 0 |
| Middle ... | 31 | 30 | 24 |
| Bottom .. | 55 | 50 | 38 |

[1]Each figure based on the inoculation of 96 discs.

parts of the plant were inoculated with various spore concentrations, the relationship was found to be similar. An example of the results obtained in these tests is given in Table 4. At all four concentrations, discs taken from the younger top leaves were more resistant than those from the older bottom leaves.

*Application of results to development of a laboratory test*

These observations on the effect of spore concentration and leaf position were applied in the development and standardization of a laboratory method of testing for partial resistance. A number of varieties that had been evaluated for partial resistance in the field in 1959 were tested for resistance by this method. The plants were grown in the greenhouse and tested approximately two months after planting. Discs were cut from leaves situated approximately one-third the distance from the top of the plant. Three plants of each variety were sampled and twenty discs were cut from each plant. The discs were placed on moist blotting paper in trays and inoculated with a drop of a spore suspension of race 1,2,3,4,6 containing approximately 200 zoospores. After one week at 60 F the percentage of sporulating discs of each variety was determined. The results of field and laboratory tests with nine varieties are given in Table 5 and show that the relative resistance of the varieties was similar in both tests.

## Discussion

It is generally accepted that partial or field resistance in the potato may be the result of one or more of three factors, viz., resistance to penetration by the spore, resistance to development of the fungus in the host after penetration and resistance through an inhibiting effect on sporulation. Van Der Zaag (11) found that the resistance of Voran and Noordeling was due both to low risk of spore penetration and to meagre sporulation. Preliminary studies using the leaf-disc method described in this paper indicate that the resistance shown by Sebago is primarily due to a resistance to spore penetration. The differences in the concentration of inoculum required to cause the same amount of disease in the four varieties used in this work may therefore be the result of differences between the varieties in one or more of the three resistance factors.

The type of resistance shown by varieties and seedlings may be an important consideration when interpreting tests done under field conditions. Varieties which are resistant largely because of an inhibitory effect on spore production, for example, may react quite differently when grown alone and when grown in experimental plots in close proximity to diseased susceptible varieties where the concentration of inoculum would be high.

The effect of age on the susceptibility of the potato has been a subject of controversy for many years. A number of workers (1, 3) have reported that age has no effect on plant susceptibility whereas others have found either a decrease (10) or an increase (6, 8) in susceptibility. Studies by Grainger (5) have helped explain these apparent contradictory results. He found that the potato plant passed through two phases of susceptibility, the first when the plant is very young and the second about flowering time with an intermediate resistant period. In addition, Lowings and Acha (7) have shown that not only is there a difference

TABLE 4.—*Effect of leaf position and concentration of inoculum on percentage of discs showing sporulation.*

| Leaf position | Spore concentration | | | |
|---|---|---|---|---|
| | 50 | 100 | 200 | 400 |
| Top | 0[1] | 1 | 3 | 9 |
| Middle | 9 | 11 | 41 | 50 |
| Bottom | 19 | 34 | 62 | 74 |

[1]Each figure based on the inoculation of 24 discs.

TABLE 5.—*Partial resistance of varieties as shown by laboratory and field tests.*

| Variety | Laboratory test | Field test |
|---|---|---|
| Ackersegen | 0[1] | Highly Resistant |
| Calrose | 0 | Highly Resistant |
| Alpha | 13 | Resistant |
| Noordeling | 12 | Resistant |
| Voran | 22 | Resistant |
| Sebago | 36 | Moderately Resistant |
| Arran Pilot | 51 | Susceptible |
| Chippewa | 58 | Susceptible |
| Bintje | 61 | Susceptible |

[1]Percentage of discs showing sporulation of the 60 inoculated.

in the susceptibility of leaves from various positions on the plant, as shown in this paper, but that the relative susceptibility of leaves from each part changes as the plant ages. These findings suggest that in order to accurately assess the relative partial resistance of seedlings and varieties under laboratory conditions all plants must be tested at the same stage of growth, the leaves used must be taken from corresponding positions on each plant, and tests must be made when the plants are at the same stage of growth as when they are normally attacked in the field.

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# FACTORS AFFECTING AND METHODS OF DETERMINING POTATO CHIP QUALITY[1]

ORA SMITH[2]

Potato processing in the United States is increasing at a very rapid rate. It has risen from practically nothing in 1940 to about 97 million bushels in 1960. This is about 30% of all potatoes consumed as food in this country. About one half the total amount processed is potato chips. This business continues to increase at a very healthy rate and is expected to reach the $500,000,000 volume this year. Potatoes for chips are grown in all the important potato producing areas and potato chip processing plants are located in every state of our country.

This increase in volume of chip sales is largely the result of extensive research by many workers on the methods of growing and storing potatoes best suited for chip manufacture. Research on various phases of processing potatoes also has improved chip quality, color, flavor, attractiveness and shelf life of the product.

## CULTURAL CONDITIONS THAT AFFECT PROCESSING QUALITY OF POTATOES

Much information on this topic has been developed during the past 10 years. A great deal is known about the importance of such factors as variety, soil type, date of planting, kind and amount of fertilizer applied, rainfall, irrigation and soil moisture, spraying for the control of insects and diseases, killing potato vines, use of sprout inhibitors and date of harvest on specific gravity of tubers and color and quality of potato chips. Information which has been known for some time and which is now in fairly wide practice will not be repeated here.

Recent information from several sources indicates the harmful effects of high soil moisture especially late in the season, whether by heavy rainfall or excessive and late irrigation. This often results in lower specific gravity tubers and a change in chemical composition which increases the hazards of producing chips of light color especially after storage and reconditioning.

In an experiment in 1959 in Western New York with eleven varieties no irrigation water was applied during the growing season until immediately after the first harvest on August 20. Water was applied at frequent intervals until late in the season in an effort to simulate soil moisture conditions of heavy rainfall late in the season.

*Irrigation and specific gravity* — Although rainfall was abnormally high in October and November there were rather marked differences in specific gravity of potatoes grown with and without irrigation late in the season. At the seven harvests after irrigation was started, potatoes in the irrigated area averaged 0.0025 lower in specific gravity than those not irrigated. Data for two of the eleven varieties are shown in Table 1.

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TABLE 1.—*Effect of rainfall, irrigation and date of harvest on specific gravity of potatoes. 1959.*[1]

| Variety and treatment | Date of harvest | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sept. 8 | Sept. 23 | Oct. 3 | Oct. 10 | Oct. 24 | Oct. 30 | Nov. 7 | Av. |
| *Katahdin* | | | | | | | | |
| Not irrigated | 1.064 | 1.068 | 1.070 | 1.067 | 1.067 | 1.064 | 1.070 | 1.069 |
| Irrigated | 1.065 | 1.064 | 1.065 | 1.068 | 1.059 | 1.065 | 1.065 | 1.064 |
| *Russet Burbank* | | | | | | | | |
| Not irrigated | 1.082 | 1.078 | 1.085 | 1.078 | 1.081 | 1.083 | 1.073 | 1.080 |
| Irrigated | 1.076 | 1.075 | 1.078 | 1.084 | 1.079 | 1.077 | 1.078 | 1.078 |
| Rainfall preceding week, inches | 0.07 | 0.11 | 0.89 | 3.71 | 0.38 | 1.20 | 2.33 | |

[1]A Potato Chip Institute potato hydrometer was used in determining specific gravity.

*Irrigation and chip color* — The only harvest at which chip color, of the 11 varieties of irrigated potatoes, averaged lighter than those not irrigated was the first harvest (September 8) after application of irrigation water. Data for two of the eleven varieties as determined with the Hunter Color Difference Meter are shown in Table 2.

The data of Table 2 substantiate the experiences of potato growers and processors in that they have considerable trouble in maintaining acceptable color in chips made from stored potatoes following seasons of excessive rainfall, particularly if it occurs late in the season.

*Soil and air temperature and chip color* — There is a good relation between soil and air temperature and chip color. Chips were very light from harvests where average soil and air temperatures ranged from 50 F to 70 F for a week preceding harvest. When average soil temperatures and lowest soil temperatures were less than 50 F for one week preceding harvest, chip color was darker. When these conditions prevailed for two weeks preceding harvest the chips were still darker in color and when it persisted for three consecutive weeks the chips were too dark to be accepted by the trade in most areas (Table 2 and Figs. 1 and 2). This is additional evidence against the advisability of delaying harvest until the potatoes are exposed to low temperatures in the field.

*Spraying plants with chelating and sequestering chemicals* — A number of years ago during research on after-cooking darkening of potatoes the author found several chemicals which, when sprayed on plants during the growing season, appeared to result in lighter color chips. Work on this phase is still in progress. The most promising of the materials applied are sodium bisulfite, chloro IPC, $Na_4EDTA$ and trisodium salt of N-hydroxyethylethylenediaminetriacetic acid (Versenol) (Fig. 3).

## PREVENTING OR DELAYING SUGAR DEVELOPMENT IN POTATOES BY TREATING WITH SULFUR DIOXIDE GAS

Treatment of potatoes with relatively low concentrations of sulfur dioxide for 24 to 48 hours apparently affects the chemical reactions which

TABLE 2.—*Effect of rainfall, irrigation, date of harvest and soil temperature on color of potato chips (Rd).*[1] *1959.*

| Variety and treatment | Date of harvest | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sept. 8 | Sept. 23 | Oct. 3 | Oct. 10 | Oct. 24 | Oct. 30 | Nov. 7 | Av. |
| *Katahdin* | | | | | | | | |
| Not irrigated ..... | 36.8 | 24.7 | 27.5 | 23.3 | 18.1 | 15.0 | 6.5 | 21.7 |
| Irrigated ..... | 29.6 | 26.2 | 24.1 | 19.4 | 12.7 | 12.6 | 8.2 | 19.0 |
| *Russet Burbank* | | | | | | | | |
| Not irrigated ..... | 33.2 | 31.4 | 27.7 | 24.2 | 21.5 | 17.2 | 13.8 | 24.1 |
| Irrigated ..... | 34.4 | 28.8 | 17.8 | 19.0 | 14.4 | 9.4 | 13.5 | 19.6 |
| Temperature[2] ..... | 61.4 | 53.5 | 56.6 | 56.2 | 47.6 | 47.7 | 44.1 | .. |
| Lowest temperature[3] ..... | 58 | 49 | 54 | 53 | 45 | 44 | 42 | .. |

[1]Numbers above 16.0 indicate an acceptably light color chip. The higher the number, the lighter the chips.
[2]Average soil temperature during 7 days preceding harvest.
[3]Lowest soil temperature during 7 days preceding harvest.

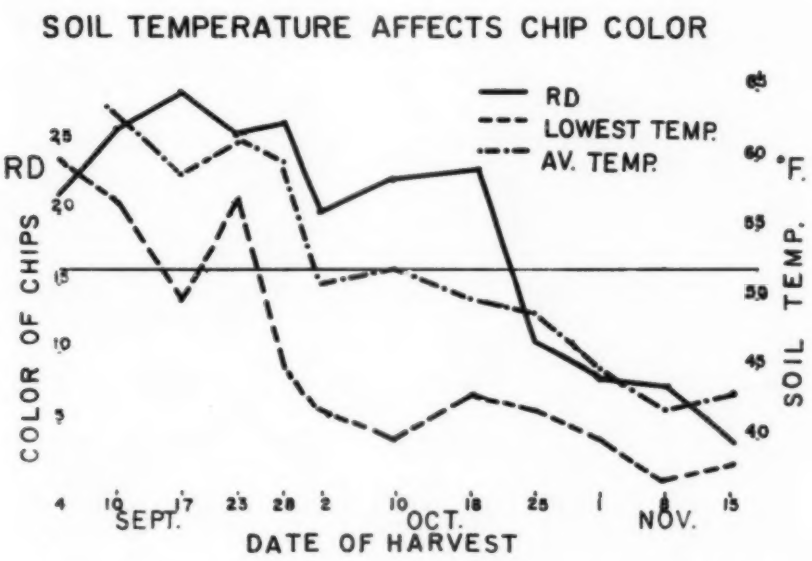


FIG. 1.—Effect of soil temperature on average chip color of nine potato varieties — 1958.

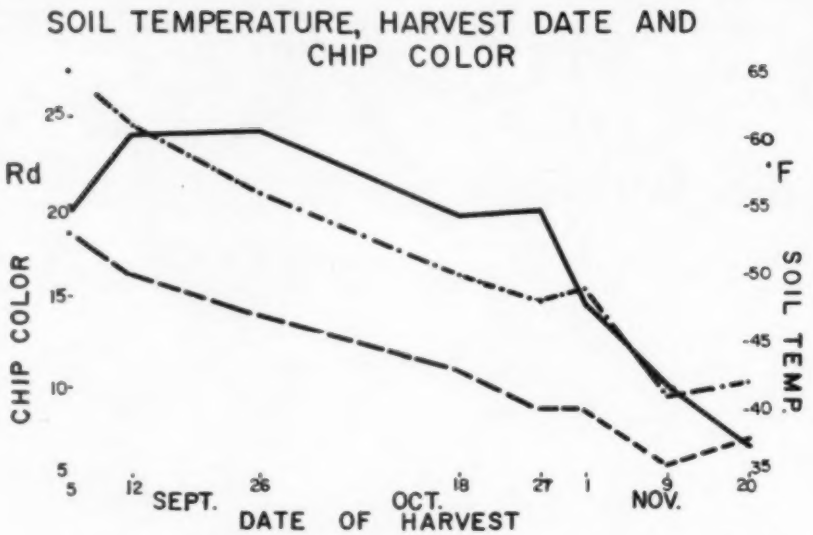


FIG. 2.—Effect of average soil temperature one week preceding harvest on chip color of Russet Rural potatoes — 1958.

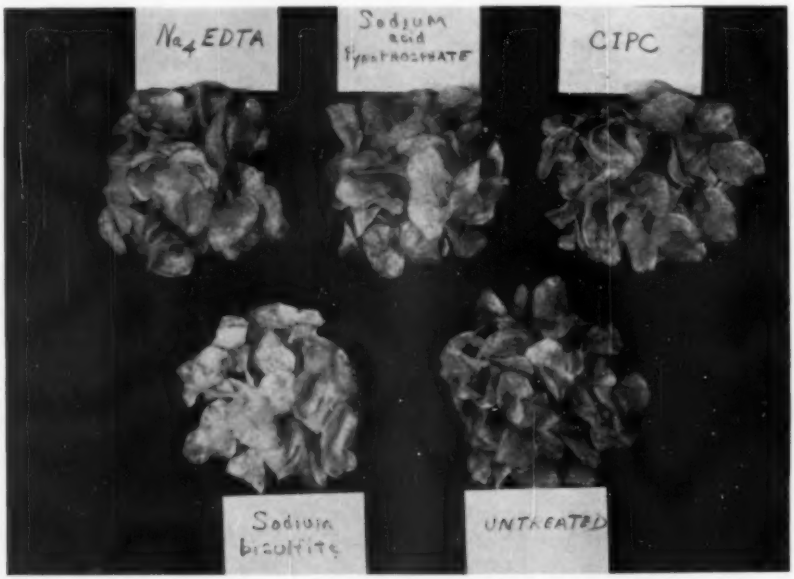


FIG. 3.—Effect of field spray applications on chip color. Plants were sprayed once in August, harvested in October, stored at 40 F. and conditioned 19 days at 75 F. Fried January 17, 1958.

usually results in accumulation of reducing sugars at low temperatures. Potatoes treated with $SO_2$ gas shortly after harvest, when reducing sugars are at a low level, will, during storage at 40 F, accumulate reducing sugars at a very much slower rate than those untreated. This delay in the accumulation of sugars results in a prolonged storage period during which treated potatoes will process into light color chips (Fig. 4). On the other hand when potatoes with a rather high concentration of reducing sugars are treated with $SO_2$, disappearance of the sugars is delayed when these potatoes are reconditioned at 70 F.

### Rapid Methods of Predetermining Chip Color

In search for quicker, easier and accurate methods of measuring sugar content of potatoes and of forecasting color of potato chips several promising methods were encountered. One of the methods determines quite accurately within one minute the glucose content of a potato or potato slice. Another method, but not quite so adaptable to indusry procedures, determines the reducing sugar content of a sample of 5 drops of potato juice. These methods are adaptations of clinical methods of determining sugars in urine of diabetics. During the past 13 months these methods were tried on over 3,000 individual tubers by frying a representative portion of each of these tubers to correlate chip color with results of the sugar tests. Many varieties and numerous growing and storing conditions were represented in these tests. The relationship between color change in the test and color of chips as measured by the Hunter Color Difference Meter is very good.

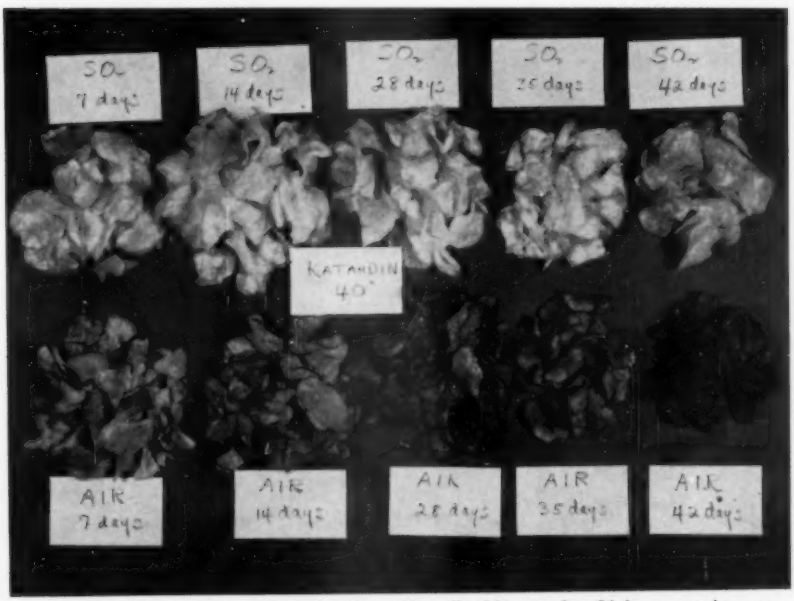


Fig. 4.—Katahdin potatoes treated with sulfur dioxide gas for 24 hours at low concentration. Stored at 40 F. and fried after 7, 14, 28, 35 and 42 days.

The "Chip Color Tester" is a simple strip test for glucose based on the use of an enzyme glucose oxidase which is impregnated in a roll of test paper. The glucose oxidase in the presence of air or oxygen changes the glucose to gluconic acid. Ortho tolidine in the tape acts as an indicator. When no glucose is present in the tuber the tape remains the original yellow color after being moistened between two portions of a cut or sliced potato. If glucose is present the tape turns green; the higher the glucose content the darker green the color of the tape. Potatoes which indicate more than ¼% glucose on the tape rarely will fry to an acceptably light color. Likewise those showing ¼% of glucose almost always fry to a light color (Table 3). Figures in columns 3 and 6 indicate per cent glucose and the variation in the same slice from apical to basal portions of tubers. Each figure in columns 3 and 6 represents a large number of identical readings (not averages) showing per cent glucose by the chip color tester and the extremes of high and low readings in each slice. The chip colors of these same slices as shown by Rd and PCI chart are averaged and shown in columns 1 and 2 and 4 and 5. Separate solutions of glucose oxidase and o-tolidine also produce the color reaction.

TABLE 3.—*Relation of "Chip Color Tester" reading to chip color. Twelve varieties, irrigated and not irrigated, harvested at 7 different times from September 8 to November 7, 1959.*

| Irrigated | | | Not irrigated | | |
|---|---|---|---|---|---|
| Chip color | | Chip color | Chip color | | Chip color |
| Rd[1] | PCI chart[2] | tester[3] | Rd[1] | PCI chart[2] | tester[3] |
| 24.6 | 3.5 | 0 | 27.1 | 2.8 | 0 |
| 20.5 | 4.9 | 0-1/10 | 23.3 | 3.7 | 0-1/10 |
| 21.1 | 4.1 | 1/10 | 22.1 | 4.0 | 1/10 |
| 18.6 | 5.9 | 0-1/4 | 21.0 | 4.5 | 0-1/4 |
| 16.1 | 5.8 | 0-1/2 | 19.0 | 5.0 | 1/10-1/4 |
| 19.8 | 5.1 | 0-2 | 17.5 | 5.8 | 1/4 |
| 14.9 | 7.2 | 1/10-1/2 | 16.8 | 6.2 | 0-1/2 |
| 13.7 | 7.6 | 1/10-2 | 16.9 | 6.6 | 0-2 |
| 9.2 | 8.4 | 1/4 | 16.7 | 6.8 | 1/10-2 |
| 8.3 | 8.7 | 1/2 | 12.3 | 7.6 | 1/2 |
| 7.4 | 9.0 | 2 | 8.3 | 8.8 | 2 |
| 6.2 | 10.0 | 1/2-2 | .. | .. | .. |

[1]The higher the number the lighter the chip color. Those above 16.0 are commercially acceptable.
[2]Proposed color reference standard, National Potato Chip Institute, January 25, 1954; Form 1206U. Numbers above 7 are too dark for commercial acceptance.
[3]Per cent glucose and variation in the same slice from apical to basal portions of tubers.

Another procedure involves the use of 5 drops of potato juice and the method of a registered trademark name test known as "Clinitest". Clinitest, a self heating copper reduction type of test, has been used a number of years for quantitation of sugar in urine of those suspected or known to have diabetes. As this test gives quick and accurate results it is widely used by physicians, laboratory workers, technicians, nurses and patients. Until the present work presented here, however, no one has considered its possible application to the problem of our industry, namely the predetermination of chip color by measuring the reducing sugar content

of potatoes. This test is not as convenient as the "Chip Color Test" described above.

There is very good relationship between the color developed in the diluted potato juice and the color of chips made from the remaining portion of the same potatoes. Data in Table 4 show that tubers with Clinitest readings of 1/10% reducing sugars or less resulted in light colored chips of commercial acceptance.

TABLE 4.—*Relation of Clinitest method of measuring reducing sugar content of potatoes and resultant chip color. 1959.*

| Variety | Clinitest % sugars | Chip color (Rd)[1] | P.C.I. color chart[2] | Clinitest % sugars | Chip color (Rd)[1] | P.C.I. color chart[2] |
|---|---|---|---|---|---|---|
| | Irrigated | | | Not irrigated | | |
| Russet Burbank | 3/8 | 9.4 | 9.5 | 1/10 | 17.2 | 5.2 |
| Merrimack | 1/10 | 19.7 | 5.2 | 1/10 | 16.6 | 5.5 |
| Plymouth | 1/6 | 13.9 | 6.7 | 0 | 19.9 | 5.1 |
| Delus | 1/10 | 23.9 | 4.1 | 1/20 | 17.8 | 5.5 |
| Russet Rural | 1/6 | 12.3 | 7.0 | 1/6 | 13.8 | 6.9 |
| Katahdin | 3/8 | 12.6 | 7.7 | 1/6 | 15.0 | 6.7 |
| Early Ohio | 1/10 | 30.7 | 4.5 | 1/10 | 21.8 | 5.2 |
| Sebago | 1/20 | 24.6 | 3.7 | 1/10 | 20.1 | 4.7 |
| Saco | 1/4 | 11.5 | 8.0 | 1/10 | 22.8 | 4.0 |
| Kennebec | 1/4 | 12.9 | 7.5 | 1/20 | 19.1 | 5.0 |
| Cherokee | 1/10 | 18.4 | 6.5 | 1/20 | 22.1 | 4.5 |

[1]The higher the number the lighter the chip color. Those above 16.0 are commercially acceptable.

[2]National Potato Chip Institute chart 1206U. Numbers above 7 are too dark for commercial acceptance.

## SUMMARY

Potato processing in the United States is rapidly increasing, now accounting for about 30% of all potatoes consumed as food. About one-half of this volume is in the form of potato chips. Better methods of growing and storing potatoes and improved techniques of potato chip processing as a result of research has increased the quality, color, flavor and shelf life of the product, thus increasing their sales and consumption.

High soil moisture late in the growing season as a result of heavy rainfall or irrigation lowers specific gravity of potatoes and results in darker color chips made from potatoes grown under those conditions.

There is good relation between low soil and air temperatures late in the growing season and color of chips from potatoes exposed to those conditions.

Certain chelating and sequestering chemicals applied as a foliar spray to potatoes appear promising for improving the color of chips.

Development and accumulation of reducing sugars in potatoes stored at 40 F. are greatly retarded by short exposure of potatoes to sulfur dioxide gas before storage, resulting in lighter color chips.

Two rapid methods have been developed for predetermining color of potato chips. The "Chip Color Tester" which tests for glucose and the "Clinitest" method which determines reducing sugars of potatoes, accurately and quickly predetermine potato chip color.

# YIELD, QUALITY, AND PHOSPHORUS UPTAKE OF POTATOES AS INFLUENCED BY PLACEMENT AND COMPOSITION OF POTASSIUM FERTILIZERS[1]

K. C. Berger, P. E. Potterton, and E. L. Hobson[2]

## Introduction

Although the phosphorus requirement of potatoes is low, compared with nitrogen or potassium, it is difficult for potatoes to obtain phosphorus from soil or fertilizer. The phosphorus content of potato soils tends to increase and yet heavy phosphate fertilizer applications are required for maximum yields. The possibility of chloride interference with phosphorus uptake seems likely because of the large amounts of potassium chloride usually applied in potato fertilizers.

The chloride and sulfate ions, along with phosphate and nitrate, are all essential to the growth of plants. Of these, chloride is required to the extent of only 100 to 200 ppm in dry tissue according to Broyer (2), whereas the others are required in amounts from 0.2 to 2.0%. However, chloride can be accumulated by plants in concentrations exceeding 5.0% (4).

Ion absorption studies with excised roots in the laboratory have indicated that the ability of plants to absorb much greater concentrations of anions than necessary for growth results in reduced concentrations of other ions of the same charge. For example, Epstein (3) showed such antagonistic ion effects in the substitution of selenate ions for sulfate ions by plants.

Soluble magnesium appears to increase phosphorus uptake by some crops (5). Because potatoes are quite generally grown on strongly acid soils, magnesium deficiencies are widespread.

A series of experiments were started in 1956 to determine the influence of chloride, sulfate, and magnesium on the uptake of phosphorus, yield and quality of several varieties of potatoes.

## Materials and Methods

The effect of fertilizer chlorides and sulfates, and of magnesium on yield, quality, and phosphorus uptake was studied on three varieties of potatoes grown on three different soil types. The potato varieties were Russet Burbank, grown on a Plainfield sand; Chippewa, grown on Antigo stony loam; and Kennebec, grown on Omega fine sand. Foliage diseases and insect damage were kept to a minimum by spraying with pesticides at approximately weekly intervals.

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[2]Professor of Soils, formerly Research assistant (now with Spencer Chemical Company, Kansas City, Missouri), and formerly Research assistant (now with Shell Development Company, Modesto, California) respectively.

A randomized complete block design was used with treatments replicated four times. Each treatment consisted of four 60-foot rows with row spacings of three feet. Fifty foot lengths of the center two rows were harvested for yield. Random sub-samples of potatoes were taken from each plot area at harvest for specific gravity determinations.

Equal amounts of potassium, as the chloride and the sulfate, were applied in broadcast as well as row applications. In addition, sulfate of potash-magnesia was applied in a broadcast application. These treatments all supplied 205 pounds per acre of $K_2O$.

While the above treatments supplied equal concentration of $K_2O$, the concentration of anion carriers were not equal. Thus the concentration of $Cl^-$ ions was approximately 2.0 times greater than the concentration of $SO_4^=$ ions. Two additional treatments, provided twice the concentration of sulfate ions as that of the chloride.

Results of the soil analyses from the various plot sites are given in Table 1. All fields were previously unlimed except those at Hancock where light to heavy applications of dolomitic lime had been applied several years previously. The pH of unlimed Plainfield sand soils in this area is about 5.2.

The above ground portion of the potato plants were analyzed at 3 different dates during the growing season.

Phosphorus content was highest in early stages of growth and tended to decrease throughout the growing season.

Plant tissue samples were taken periodically throughout the growing season, dried, and ground through a Wiley mill prior to phosphorus analy-

TABLE 1.—*Results of soil analyses for experimental plots, prior to fertilization.*

| Year of experiment | Soil type | Variety grown | Ph | Pounds per acre available | | |
|---|---|---|---|---|---|---|
| | | | | (N) Nitrogen | (P) Phosphorus | (K) Potassium |
| 1956 | Omega sand | Kennebec | 5.1 | 185 | 165 | 310 |
| 1957 | Omega sand | Kennebec | 5.1 | 150 | 185 | 180 |
| 1957 | Plainfield sand | Russet Burbank | 5.5 | 125 | 60 | 150 |
| 1958 | Antigo stony loam | Chippewa | 5.1 | 190 | 150 | 240 |
| 1958 | Plainfield sand | Russet Burbank | 6.7 | 125 | 45 | 145 |
| 1959 | Omega sand | Kennebec | 5.1 | 150 | 170 | 175 |
| 1959 | Plainfield sand | Russet Burbank | 6.4 | 175 | 45 | 160 |
| 1959 | Antigo stony loam | Chippewa | 5.1 | 175 | 170 | 300 |

sis. Phosphorus was determined on a 0.4N HCl extract of one gram samples ashed for two hours in a muffle furnace at 500 C. The molybdate-vanadate method of Barton (1) was used with the color intensity determined on a Bausch and Lomb Spectronic 20 set at a wave length of 470 mu.

## Results

### *Russet Burbank potatoes — Plainfield Sand Experiments*

Potatoes in the Russet Burbank experiments were adequately supplied with water throughout the season with supplemental irrigation.

As shown in Table 2, higher yields and phosphorus uptake were obtained when the potassium salts were applied broadcast. These treatments separated the potassium salts from the phosphorus and nitrogen fertilizer banded in the row. Potassium sulfate applied in the row with the phosphorus and nitrogen fertilizers during the 1948 growing season increased potato yields and phosphorus uptake over potatoes receiving equivalent amounts of potassium in the row as potassium chloride. In 1959, yields and phosphorus uptake were similar, but the plants receiving potassium sulfate were darker green in color and exhibited a more healthy appearance throughout the growing season. It is believed that the potato plots receiving potassium sulfate grew more rapidly and possibly exhausted their available phosphorus prior to maximum tuber development.

The highest yield, 845 bushels per acre, was obtained during the 1959 growing season where 783 pounds per acre of sulfate of potash-magnesia was applied broadcast, 500 pounds of 10-35-5 fertilizer banded in the row, and 500 pounds of ammonium nitrate applied during the growing season. Furthermore, greater phosphorus uptake, particularly early in the season, was obtained during both growing seasons by this treatment.

Results given in Table 5 show that in every case the application of soluble magnesium, in the form of sulfate of potash-magnesia, increased the phosphorus content of the potato plants. Yield differences were not significant, however; but in two out of three years the highest yields were obtained with this treatment. These fields had been previously limed with dolomitic limestone and were less acid than other fields used in these experiments as shown in Table 1.

Specific gravity determinations conducted on potato tubers grown in this 1959 test showed that broadcasting the potassium salt increased the quality of the tuber. Potassium sulfate and sulfate of potash-magnesia applied broadcast with 500 pounds of 10-35-5S fertilizer in the row gave the highest specific gravity readings.

### *Chippewa potatoes — Antigo Stony Loam Experiments*

In general, the soils in these fields were very strongly acid, and high in available phosphorus, as shown in Table 1.

Results given in Table 3 show the highest yield and greatest phosphorus uptake were obtained when sulfate of potash-magnesia was applied broadcast and the phosphorus and nitrogen fertilizer banded in the row. The potatoes were not irrigated in these experiments.

During the 1958 growing season higher yields and phosphorus uptake were obtained when the potassium salts were applied broadcast, thereby

TABLE 2.—*Yields, phosphorus uptake, and quality of Russet Burbank potatoes as influenced by various fertilizer treatments, grown in irrigated Plainfield Sand, Hancock.*

| Fertilizer treatments[1] (Pounds per acre) | | | Yield (bu/A)[2] | | Per cent tissue P (dry wt. basis) 79 days after planting | | Specific gravity |
|---|---|---|---|---|---|---|---|
| Treat. No. | Banded in row | Broadcast | 1958 | 1959 | 1958 | 1959 | 1959 |
| 1 | None | None | 486 | 645 | 0.18 | 0.19 | 1.073 |
| 2 | 500 10-35-5 Cl[3] | 300 0-0-60 Cl | 761 | 754 | 0.28 | 0.29 | 1.073 |
| 3 | 500 10-35-5 Cl plus 300 0-0-60 | None | 689 | 745 | 0.24 | 0.28 | 1.070 |
| 4 | 500 10-35-5 S[4] | 360 0-0-50 S | 747 | 805 | 0.27 | 0.30 | 1.075 |
| 5 | 500 10-35-5 S plus 360 0-0-50 | None | 735 | 735 | 0.26 | 0.29 | 1.071 |
| 6 | 500 10-35-5 Cl plus 130 0-0-60 | 175 0-0-60 Cl | .. | 786 | .. | 0.31 | 1.074 |
| 7 | 500 10-35-5 S plus 745 0-0-50 | None | .. | 764 | .. | 0.26 | 1.070 |
| 8 | 500 10-35-5 SPM[5] | 783 0-0-23 SPM | 735 | 845 | 0.30 | 0.31 | 1.075 |
| | LSD at 5% level | | 58 | 87.8 | | | |

[1]All plots received 300 lbs. 33-0-0 sidedressed and 200 lbs. 33-0-0 applied through the irrigation system.
[2]Average of four replicates.
[3]Cl = all potassium applied as potassium chloride.
[4]S = all potassium applied as potassium sulfate.
[5]SPM = potassium applied as sulfate of potash magnesia.

TABLE 3.—*Yields, phosphorus uptake, and quality of Chippewa potatoes as influenced by various fertilizer treatments, grown in Antigo Stony Loam, Starks.*

| Fertilizer treatments[1] (Pounds per acre) | | Yield (bu./A.)[2] | | Per cent tissue P (dry weight basis) | | Specific gravity |
|---|---|---|---|---|---|---|
| Banded in row | Broadcast | 1958 | 1959 | 1958 50 days after planting | 1959 35 days after planting | 1959 |
| None | None | 295 | 363 | 0.21 | 0.35 | 1.083 |
| 500 10-35-5 Cl[3] | 300 0-0-60 Cl | 549 | 675 | 0.36 | 0.54 | 1.077 |
| 500 10-35-5 Cl<br>300 0-0-60 | None | 488 | 692 | 0.30 | 0.51 | 1.075 |
| 500 10-35-5 S[4] | 360 0-0-50 S | 531 | 646 | 0.35 | 0.56 | 1.075 |
| 500 10-35-5 S<br>360 0-0-50 | None | 497 | 629 | 0.35 | 0.52 | 1.079 |
| 500 10-35-5 Cl<br>130 0-0-60 | 175 0-0-60 Cl | .. | 668 | .. | 0.54 | 1.071 |
| 500 10-35-5 S<br>745 0-0-50 | None | .. | 673 | .. | 0.50 | 1.073 |
| 500 10-35-5 SPM[5] | 783 0-0-23 SPM | 528 | 704 | 0.37 | 0.56 | 1.073 |
| LSD at 5% level | | 78 | 65.1 | | | |

[1]All treatments, except the control, received 160 pounds per acre of 33-0-0 in 1958. All treatments, except the control, received 240 pounds per acre of 33-0-0 in 1959.
[2]Average of four replicates.
[3]Cl = all potassium applied as potassium chloride.
[4]S = all potassium applied as potassium sulfate.
[5]SPM = all potassium applied as sulfate of potash-magnesia.

separated from the phosphorus and nitrogen fertilizer band in the row. A comparison of row placements shows that potassium sulfate was superior to potassium chloride.

The 1959 growing season was very favorable for potato production as shown by increased potato yields compared with the 1958 potato yields. The yields of plots treated with KCl were slightly higher than those treated with $K_2SO_4$. However, the yield data are somewhat erratic when compared with the notations made on plant appearances throughout the growing season. The potato vines on the potassium sulfate plots maintained a darker green color and more thrifty appearance throughout the growing season. On the other hand, the leaves of the potatoes fertilized with potassium chloride were light green in color and produced a spindly top growth. Although not marked, similar observations were noted on the Russet Burbank—Plainfield Sand Experiments. Here again, it is believed that the potato plots receiving potassium sulfate, grew more rapidly and thereby exhausted their supply of available phosphorus prior to maximum growth of tubers.

In 1958 results were somewhat erratic, possibly because a portion of the field was damaged slightly by excess water which stood in part of the field early in the season. This is reflected in the large difference required for significance.

Plant tissue taken from plots receiving broadcast applications of potassium, as either the chloride or sulfate salts, showed higher phosphorus uptake than did plants receiving the same potassium salts banded in the row (Table 3). With similar placement of the potash salts, potassium sulfate gave plant tissue of higher phosphorus content than did plants fertilized with potassium chloride.

Results given in Table 5 show that the application of sulfate of potash-magnesia greatly increased the phosphorus content of the potato vines over those receiving sulfate. Although yields were not increased by this treatment in 1958 they were significantly increased in 1959. Magnesium deficiency symptoms were apparent in 1959.

Specific gravity determinations made on potato tubers of the 1959 season showed that highest specific gravity, indicating better quality, was obtained when potassium sulfate was banded in the row.

*Kennebec potatoes — Omega Sand Experiments*

Data presented in Table 4 for the years 1956 and 1959 show that although yield differences were considerably greater for the 1956 experiment, potatoes receiving broadcast applications of potassium sulfate gave considerably higher yields than did plants receiving potassium chloride. Broadcast applications of the potassium salt, thereby separated from the banded phosphorus and nitrogen, in general, produced higher yields and consistently higher phosphorus uptake during both years. The potatoes in these experiments were not irrigated.

The results given in Fig. 1 show the phosphorus content of Kennebec potato vines from the 1956 season at three stages of growth, 40, 70, and 100 days after planting. In general phosphorus content declines in the vines with increasing maturity. At the early growth stage potatoes receiving the broadcast treatments of potash were similar in phosphorus content

TABLE 4.—*Yields, phosphorus uptake, and quality of Kennebec potatoes as influenced by various fertilizer treatments, grown on Omega Sand. Red Dot Foods, Inc.*

| Fertilizer treatments[1] (Pounds per acre) | | Yield (bu/A)[2] | | Per cent tissue P (dry wt. basis) 40 days after planting | | Specific gravity | |
|---|---|---|---|---|---|---|---|
| Banded in row | Broadcast | 1956 | 1959 | 1956 | 1959 | 1956 | 1959 |
| None | None | 128 | .. | .. | .. | 1.085 | .. |
| 500 11-48-0 | 503 0-0-60 | 571 | .. | 0.57 | .. | 1.086 | .. |
| 1000 6-24-24 Cl[3] | None | 555 | .. | 0.51 | .. | 1.079 | .. |
| 500 11-48-0 | 600 0-0-50 | 588 | .. | 0.58 | .. | 1.087 | .. |
| 1000 6-24-24 S[4] | None | 570 | .. | 0.50 | .. | 1.087 | .. |
| 500 11-48-0 | 1300 Sul-po-mag | 639 | .. | 0.58 | .. | 1.084 | .. |
| None | None | .. | 169 | .. | 0.45 | .. | 1.088 |
| 500 10-35-5 Cl | 300 0-0-60 | .. | 261 | .. | 0.59 | .. | 1.067 |
| 500 10-35-5 Cl 300 0-0-60 | None | .. | 290 | .. | 0.51 | .. | 1.065 |
| 500 10-35-5 S | 360 0-0-50 | .. | 329 | .. | 0.58 | .. | 1.076 |
| 500 10-35-5 S 360 0-0-50 | None | .. | 329 | .. | 0.57 | .. | 1.077 |
| 500 10-35-5 SPM[5] | 783 0-0-23 | .. | 424 | .. | 0.62 | .. | 1.079 |
| LSD at 5% level | | 53 | 44.8 | | | | |

[1]All treatments, except the control, received 300 pounds per acre of 33-0-0 in 1956. All treatments received 400 pounds per acre of 33-0-0 in 1959.
[2]Average of four replicates.
[3]Cl = all potassium applied as potassium-chloride.
[4]S = all potassium applied as potassium-sulfate.
[5]SPM = all potassium applied as sulfate of potash-magnesia.

TABLE 5.—*Yield and quality of potatoes as influenced by soluble magnesium applied with the fertilizer.*

| Location, year, and variety | Fertilizer treatment, lbs. per acre[1] | | | Acre yield[2] | P Content of tissue[3] |
|---|---|---|---|---|---|
| | Banded in row | Broadcast | Ammonium nitrate sidedressed | | |
| | | | | bu. | % |
| Rhinelander 1956 | 500 11-48-0 | 600 0-0-50 S | 300 | 588 | 0.42 |
| Kennebec | 500 11-48-0 | 1300 0-0-23 SPM | 300 | 639 | 0.50 |
| Rhinelander 1957 | 570 10-35-5 S | 330 0-0-50 S | 200 | 387 | 0.39 |
| Kennebec | 570 10-35-5 SPM | 720 0-0-23 SPM | 200 | 447 | 0.42 |
| Hancock 1957 | 570 10-35-5 S | 330 0-0-50 S | 360 | 706 | 0.44 |
| Russet Burbank | 570 10-35-5 SPM | 720 0-0-23 SPM | 360 | 714 | 0.46 |
| Hancock 1958 | 500 10-35-5 S | 360 0-0-50 S | 600 | 747 | 0.27 |
| Russet Burbank | 500 10-35-5 SPM | 783 0-0-23 SPM | 600 | 735 | 0.30 |
| Starks 1958 | 500 10-35-5 S | 360 0-0-50 S | 160 | 531 | 0.25 |
| Chippewa | 500 10-35-5 SPM | 783 0-0-23 SPM | 160 | 528 | 0.30 |
| Hancock 1959 | 500 10-35-5 S | 360 0-0-50 S | 500 | 805 | 0.30 |
| Russet Burbank | 500 10-35-5 SPM | 783 0-0-23 SPM | 500 | 845 | 0.31 |
| Starks 1959 | 500 10-35-5 S | 360 0-0-50 S | 240 | 646 | 0.31 |
| Chippewa | 500 10-35-5 SPM | 783 0-0-23 SPM | 240 | 704 | 0.40 |
| Rhinelander 1959 | 500 10-35-5 S | 360 0-0-50 S | 400 | 363 | 0.26 |
| Kennebec | 500 10-35-5 SPM | 783 0-0-23 SPM | 400 | 424 | 0.28 |

[1]S = All potash in sulfate form, SPM = All potash in form of sulfate of potash-magnesia which contains about 23% $K_2O$ and 18.5% MgO.
[2]Average of 4 replicates.
[3]Above ground portion of plants, dry wt. basis, about 70 days after planting.

but at the later stages those receiving the sulfate of potash-magnesia treatment contained considerably more than any other.

The row applications of potash resulted in lower plant phosphorus content throughout the season except for the sulfate of potash-magnesia treatment which increased at the late stage. The results show that banded sulfate did not affect the phosphorus uptake as adversely as did the chloride.

Results given in Fig. 2 show that in general, sulfur content increased throughout the season and that plants in all treatments were adequately

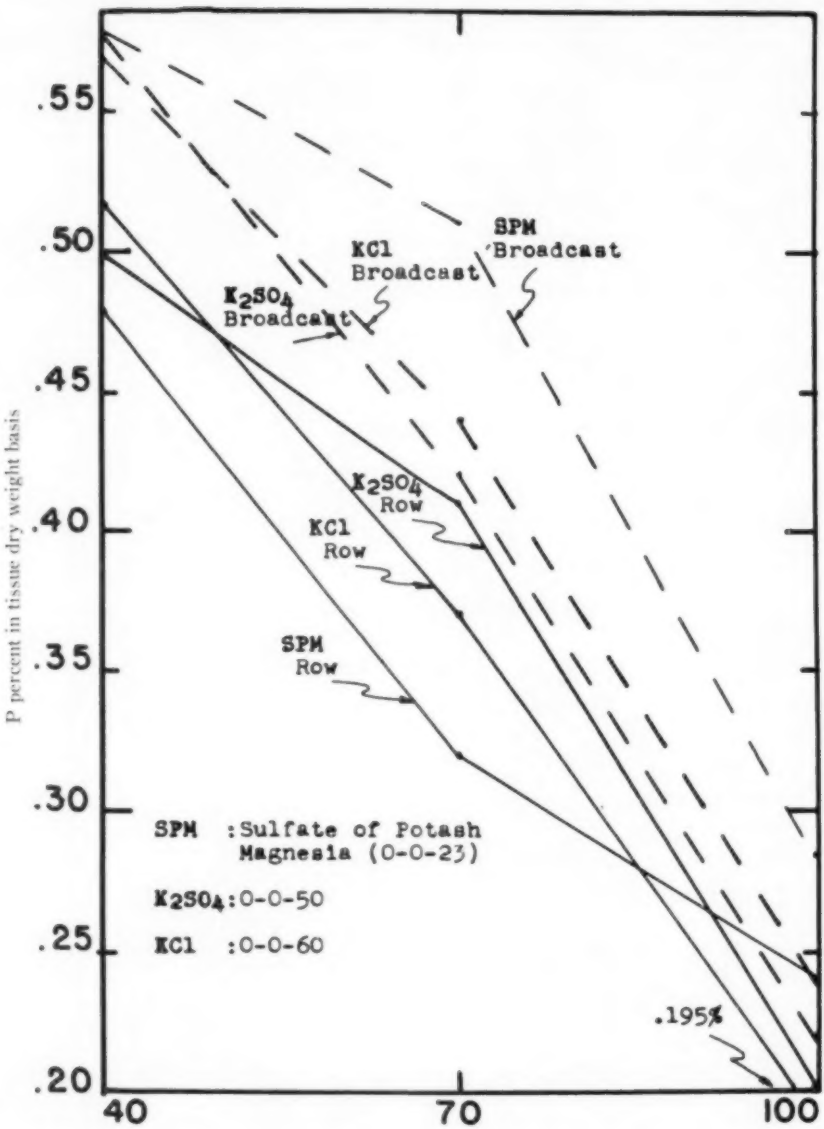


FIG. 1.—Content of phosphorus, percentage basis, in Kennebec plant tissue as influenced by source and placement of 300 lbs $K_2O$.

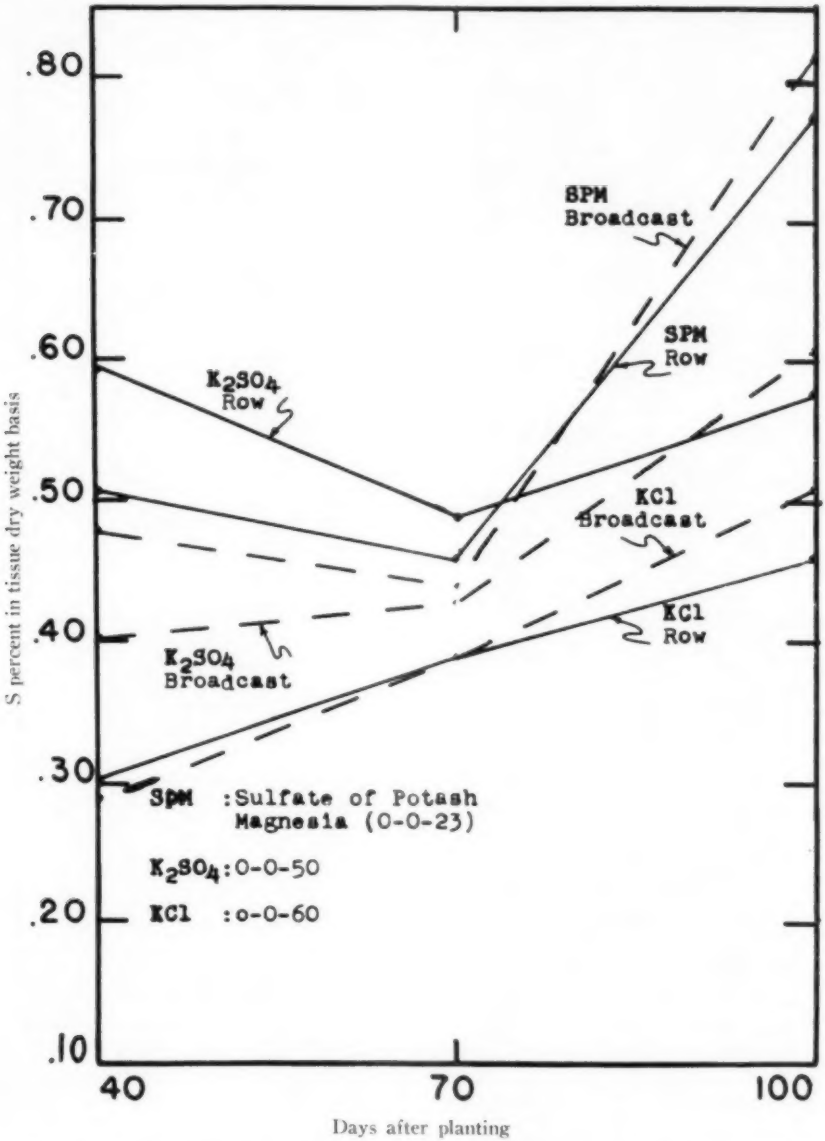


FIG. 2.—Content of sulfur, percentage basis, in Kennebec plant tissue as influenced by source and placement of 300 lbs. $K_2O$.

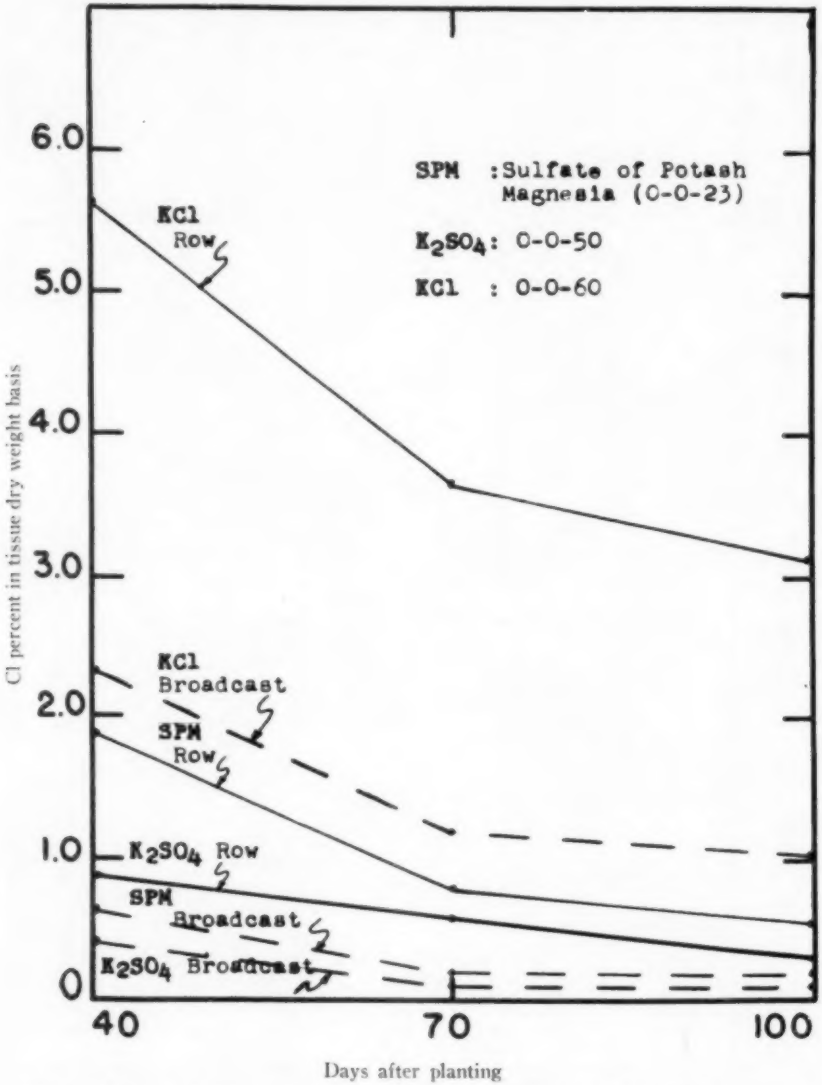


FIG. 3.—Content of chlorine, percentage basis, in Kennebec plant tissue as influenced by source and placement of 300 lbs $K_2O$.

supplied with sulphur. The potatoes on all sulfate treatments contained higher quantities of sulfur than those from the chloride treatments.

The chloride content of the vines was very high and the results given in Fig. 3 show that excessive quantities of chloride were taken up by the potatoes when potassium chloride was banded. This amounted to over 5.5% Cl at 40 days and over 3.0% Cl at the late stage and indicates why phosphorus uptake was inhibited by this treatment.

Sulfate of potash-magnesia gave highest yields and phosphorus uptake for the two-year period. This undoubtedly indicates a magnesium deficiency in this soil.

Specific gravity determinations, indicating quality, show that potassium sulfate gave the highest quality. Broadcasting the potassium salt, either as chloride or sulfate, increased the quality of the potatoes.

## Discussion

Experimental data obtained from potato trials show that phosphorus uptake was decreased when potassium chloride was banded in the row with the phosphate fertilizer. Equivalent amounts of potassium as potassium sulfate banded in the row did not show this depressive effect on phosphorus uptake.

It is believed that the more active chloride ion was in some way interfering with the phosphorus uptake mechanism. However, data obtained indicate that possibly the concentration of the anion is also interfering with phosphorus uptake because in 1959, treatments which received double the concentration of sulfate ions, banded in the row with phosphorus, resulted in decreased phosphorus uptake by potatoes in two of three trial sites.

Further data substantiating the effect of ion concentration was obtained when equivalent amounts of potassium chloride were applied broadcast and compared to banded applications of the same material. Under these conditions, the same amount of potassium chloride applied broadcast, giving less concentration of chloride with the phosphorus band, increased phosphorus uptake. In most potato trials, phosphorus uptake was increased with broadcast applications of either potassium chloride or potassium sulfate when compared with row applications of these materials. In all cases phosphate was banded.

Potato yields are closely correlated with phosphorus uptake. Therefore, yields were generally higher when the potassium salts were applied broadcast (and) the phosphate fertilizer applied in the row. During the 1959 season, the vine growth and tuber yields at Hancock and Starks were so large that the P application was inadequate. This was indicated by tissue analysis in later stages of growth and apparently resulted in a smaller difference in dry matter content. Tissue analysis given in Tables 2 and 3 reveal that phosphorus was deficient during the later stages of growth.

Quality of potatoes, based on specific gravity, was higher in all cases due to applying potassium sulfate rather than potassium chloride. Broadcasting most of the potassium resulted in higher specific gravity than did row applications. This was believed to be caused by the earlier maturity of the plant receiving broadcast applications. When maturity

was delayed, it was assumed that development of potatoes was also delayed, resulting in lower quality potatoes. Equivalent amounts of potassium sulfate banded in the row did not apparently delay maturity, thus resulting in development of higher quality potatoes. When equal amounts of potassium sulfate and chloride were mixed with the phosphate and applied in the row in bands, potassium sulfate resulted in consistently higher phosphorus content in the potato vines in the early part of the season.

The difference in shape and color of leaves was quite marked under

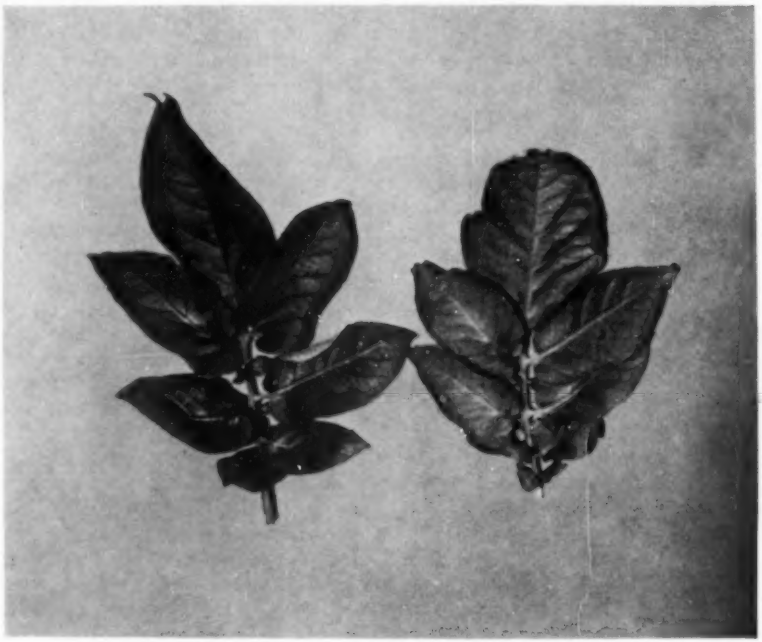

FIG. 4.—Coloration of leaves from potato plants receiving all potash in sulfate form on left, and all potash in chloride form on right. The amounts of NPK received by each were alike.

the different treatments. The plants receiving sulfate of potash had thicker, darker green leaves, when compared with those receiving chloride where they were noticeably thinner, and much lighter in color. This difference is shown in Fig. 4 in leaves of Chippewa potatoes taken from the two treatments at Starks in 1959. The light-colored leaf is from the plot receiving 500 lbs. of 10-35-5 Cl plus 300 lbs. 0-0-60 Cl in the row while the dark-colored leaf was typical of the potatoes receiving the same amount of K in the sulfate form.

## SUMMARY

Field trials were conducted for a period of several years using three

different potato varieties on three different Wisconsin soil types. Comparisons were made between band and broadcast applications of potassium salts containing chlorides and sulfates.

It is concluded that chlorides, banded in the row with the phosphorus and nitrogen fertilizer, will inhibit phosphorus uptake and reduce yield and dry matter content of potatoes as compared to sulfates. Separation of the chloride from the phosphorus fertilizer, by broadcasting the chloride and banding the phosphorus, increased phosphorus uptake and yields in most cases.

Potassium sulfate is a better source of potassium than is potassium chloride when applied banded in the row with the phosphorus and nitrogen fertilizer. In general, sulfate of potash-magnesia appeared to be the best source of potash, increasing potato yields and improving quality, in these soils.

Potatoes receiving sulfate have thicker, darker-colored leaves than do those receiving chloride. The leaves of plants receiving chloride are very light-colored and thin.

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## NEWS AND REVIEWS

### BOOK REVIEW

BACTERIAL PLANT PATHOGENS by C. Stapp. Translated by A. Schoenfeld. xviii + 292 p., 100 figs. Oxford University Press, 417 Fifth Ave., New York 16, N. Y. 1961. Price $6.75.

This is another fine contribution to the literature on bacterial plant pathogens. It was written to fill a need for a handbook for teachers and students. Although this translation was made available this year, the text was actually completed at the time W. J. Dowson's 2nd edition of *Plant Diseases Due to Bacteria* was published in 1957. Both books were written for the advanced student, and the authors have presented in a somewhat comparable manner this fascinating and specialized field in phytopathology. Fortunately, the publisher has kept the price low enough to permit the student to acquire the book for his own library.

Included in the first part of the book are sections on bacteriological technique, methods of identifying plant pathogens, serological methods of identification, identification by bacteriophages, and the classification and nomenclature of phytopathogens. The author rightfully feels that "the knowledge and correct application of bacteriological technique is absolutely essential for successful work in this specialized field."

Twenty-four bacteria that cause plant diseases in Central Europe are described in the second and major portion of this handbook. All of the bacteria are also found in the United States. The genera and species are arranged alphabetically for easy reference. Each organism is considered in detail under the following headings: description of the pathogen; disease symptoms; channels of infection; resistance; host plants; geographical distribution; and control. Selected references are listed for each species.

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### NOTICE

Copies of the Proceedings of the First Triennial Conference of the European Association for Potato Research, held at Brunswick/Volkenrode, W. Germany, concurrently with the Fourth Conference of Potato Virus Diseases, are available from Administrative Center, European Association for Potato Research, P. O. Box 20, Wageningen, The Netherlands. Price 15 Dutch Guilders per copy.

THIRD SUPPLEMENT OF THE DUTCH POTATO ATLAS: Published by H. Veenam & Zonen, Wageningen. The Netherlands. 18 p. Price $3.13.

The latest supplement to the beautifully illustrated Dutch Potato Atlas describes and illustrates in color eight recently developed varieties introduced in 1958 and 1959.

The description is concise but complete including the name of the breeder, degree of disease resistance, soil adaptation, time of maturity and best utilization.

The color illustrations of the leaves, flowers, sprouts and internal and external tuber color are excellent.

This supplement for addition to the loose leaf binder published in 1955 is a valuable addition to the descriptions of Dutch potato varieties.

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PROCEEDINGS OF THE FOURTH CONFERENCE ON POTATO VIRUS DISEASES. Edited by Drs. J. Brandes, R. Bartels, J. Volk and C. Wetter. Published by H. Veenman & Zonen N. V., Wageningen, The Netherlands. Price not known.

This paper bound book contains 23 papers on potato viruses which were presented at the Fourth Conference on Potato Virus Diseases at Braunschweig, W. Germany, September 12-17, 1960. It also contains the discussions which followed the presentation of each paper.

We consider this a very valuable book containing some of the latest research on potato viruses in Europe, Great Britain and the U. S. A. Many of the papers are printed in English and all have an English summary.

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## HIGHLIGHTS OF ANNUAL MEETING

At the annual meeting held at Wenatchee, Washington, the following officers were elected:

Robert V. Akeley — President
L. C. Young — President-Elect
William G. Hoyman — Vice-President
Henry M. Darling — Director

Richard L. Sawyer was appointed to serve as secretary for another two years.

The annual dues were increased to $6.00 in United States, Canada and Mexico and $7.00 in other foreign countries, effective January 1, 1962.

The invitation extended by Orrin Turnquist to meet at Grand Forks, Minnesota in August 1962 was accepted.

Julian Miller, G. H. Rieman and Sam Kennedy were elected to Honorary Life Membership in the Association.

## USDA ISSUES RAIL TRANSPORTATION MANUAL FOR FRESH PRODUCE SHIPPERS

Ways to maintain the quality of fresh fruits and vegetables during rail shipment, so as to deliver high quality products to the consumer, are described in a handbook issued recently by the U. S. Department of Agriculture.

Fresh produce deteriorates quickly in transit if rail cars are not properly refrigerated or heated. The railroads have made available to shippers many kinds of protective services and equipment, such as mechanical or ice refrigeration, heaters, fans, and means for precooling. These services are designed to provide and maintain a satisfactory environment for produce in rail cars and reduce losses due to decay, overripening, or chilling injury.

Marketing researchers of USDA's Agricultural Marketing Service have compiled the handbook descriptions of the services available, together with recommendations for their use. Included are discussions of containers and loading, methods of precooling, and formulas for calculating the refrigeration load.

Shippers of all the major fruits and vegetables can find in the handbook information to help them select the best and most economical protection for their commodities. The handbook considers the requirements of individual products, seasonal needs, geographical location, and cost.

Most of the recommendations are based on transportation studies conducted by USDA. For certain crops not thoroughly studied by the Department, commercial practices have been evaluated and tentatively recommended in order to provide more complete coverage of all important fruits and vegetables.

A free copy of the handbook, AH-195, "Protection of Rail Shipments of Fruits and Vegetables," may be obtained from the Office of Information, U. S. Department of Agriculture, Washington 25, D. C.

## ARIZONA POTATOES DISPLAYED

You'd have thought it was a bathing beauty contest the way the men looked them over — examining their shapes, then looking at their eyes.

Only these were Arizona potatoes — 32 varieties of them. And Arizona growers were examining them to see how good for potato chips they would become.

Potatoes have become such a big business enterprise in Arizona now. The University of Arizona College of Agriculture recently held a potato meeting for commercial growers at Mesa to discuss new varieties of Irish-type potatoes.

"Potatoes, as a business enterprise, have grown so rapidly that potatoes now are virtually equal in economic value to Arizona's famed citrus industry," Dr. Norm Oebker, horticulturist of The University of Arizona Agricultural Extension Service, said.

Acreage of potatoes grown in Arizona has increased each year until the value of potatoes to the state's economy now stands at about $8,000,000. Many of these potatoes are grown commercially for processing into potato chips, but some are also grown for the fresh market. Last year, slightly more than 10,000 acres of potatoes were grown commercially in Arizona. The primary plantings are in the areas around Phoenix, Queen Creek, Mesa, Casa Grande, Eloy, Yuma and the Harquahala Valley.

A tremendous growth in acreage planted to Kennebec potatoes has taken place in recent years, due to the demand for potato chips. Such acreage jumped 77% last year over the previous year.

Thirty-two varieties of pottaoes were shown growers at the recent U of A meeting, most of them new varieties. Some do not have names yet, carrying only numbers, such as ND 3815-1R. Others have such colorful names as Snowflake, Navajo, Cherokee, Redskin and Blanca. The potatoes shown were planted in January and February this year and grown on the Ed LeBaron ranch in Maricopa county.

Commercial growers examined the potatoes from the standpoint of size, grade, round or oblong shape, depth of eyes, and specific gravity. They studied the plant yield data and determined how many U.S. No. 1's were produced from each variety. The Arizonians determine from such examinations, among other things, how good the potato would be for "chipping" purposes, i.e., whether they will make potato chips easily and be of desirable quality.

—Robert V. McKnight, *Agricultural Extension Service, University of Arizona, Tucson, Arizona*

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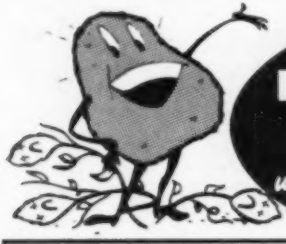

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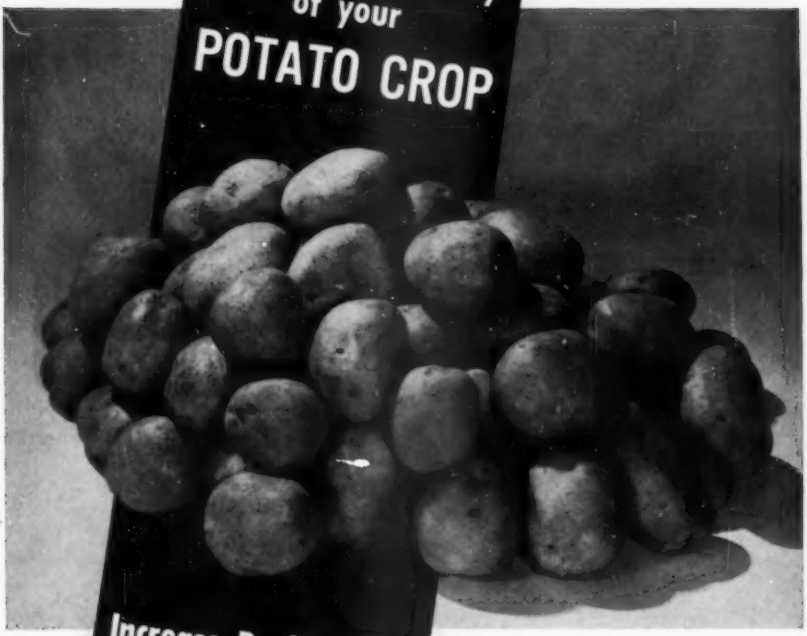

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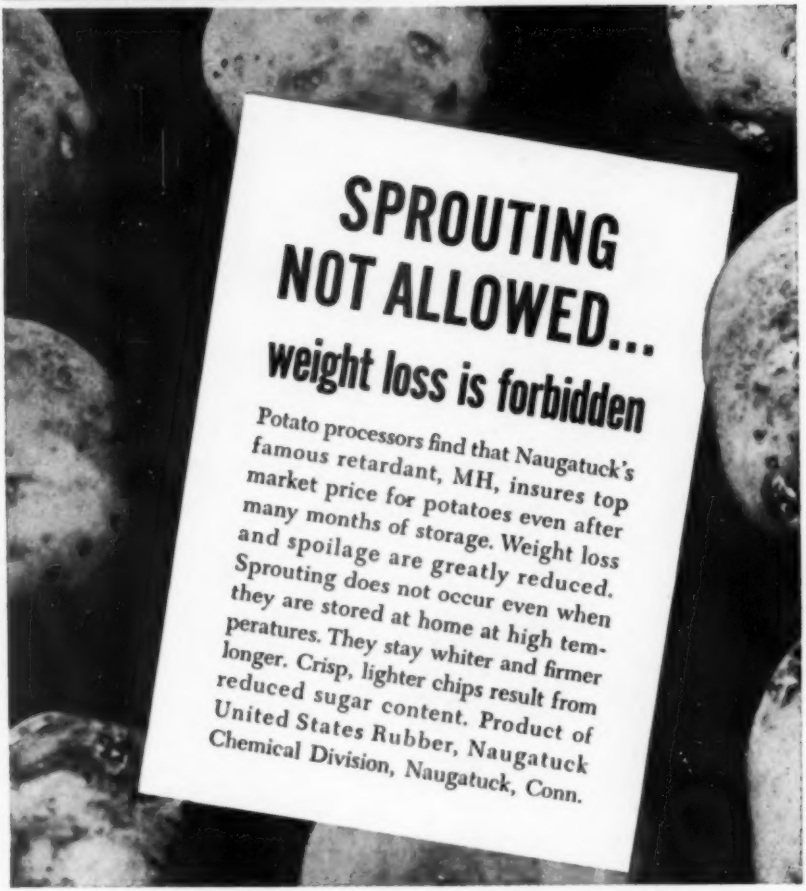
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